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A REVIEW OF NEW COMPOSITE MATERIALS FOR THERMAL PROTECTION IN AN AERO-ENGINE APPLICATION

Ibrahim Mohammed
Dept. of Aerospace Engineering Air Force Institute of Technology, Kaduna, Nigeria
ibrahimmuhd1980@gmail.com

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ABSTRACT

The paper is aimed at exploring new composite materials for thermal protection in an aero-engine application. Aluminium hybrid composites have been widely used to substitute materials in the aerospace industry because of their high thermal resistance, wear resistance and strength-to-weight ratio. This review article covers standard fire test results of different types of burners and burn-through times of the composites and polymeric materials. The paper evaluates the performance of different structural composite materials including synthetic fibres, natural fibres and some type of coating on the materials in a pool-fire scenario. It also deals with the practical use of flame retardancy and performance factors including safety in an aircraft related to polymer composites. It was found that most of the materials used could only be categorized as fire resistance materials except GLARE materials and synthetic/natural fibre composites and aerogel composites which showed the characteristic of fireproof materials.

Keywords*: Aerospace; Natural fibres; Composites; Polymers; Burners.*

I.INTRODUCTION

The increasing hours of flight require a conducive environment, and a better level of assurance in the safety and well-being of passengers, their belongings as well as the aircraft crew. The more fibrous material being used the higher the level of safety and the required results in constructing the aerospace parts. The prime root of fire accidents in aircraft is flammability which may be fended off using flame-retardant fibrous materials. Aircraft structures are designed and constructed to resist different loading scenarios during their operational life. For fire safety reasons, the Federal Aviation Administration has instituted prerequisites to safeguard the critical parts and components in aircraft[1]. The engine installation may be affected by the fire but must perform effectively and allow safe engine shutdown.

There is a possibility of increasing aircraft fire hazards when using polymer composite materials that are flammable in nature. Carbon/epoxy is the most popular polymer composite used in the outermost part of the aircraft and is a flammable material that easily ignites and burns when exposed to fire. Meanwhile, glass/phenolic composite materials are widely used in aircraft cabin interiors and performed fairly well in fire scenarios. Nowadays, new composites are being developed for cabins and external components that have the ability to increase the fire safety of aircraft such as materials with high-temperature thermoset polymer, thermoplastic or inorganic polymer matrices [2-4]. Carbon fibre-reinforced polymeric composites are lightweight and possess fire-retardant properties. Almost 50% of the materials used in modern commercial aircraft now are made from this composite [5]. Another method of increasing the matrix flame retardancy is by the use of waste DNA from the fishing industry that normally alters the clay structure, this increases the thermal property of epoxy by increasing the interaction of the epoxy and clay in nano-composites [6]. Asante *et al.*[7] reported in their research that the increase of expandable graphite in polymer composite leads to a delay in ignition time, and reduces the ignition temperature and thermal conductivity of the composites.

To withstand different fire events and shocks that may befall aircraft structures during their working time, different loading scenarios have to be considered. The safety of crew and passengers in aircraft take-off, flight manoeuvres and landing is associated with loading scenarios. Cahill [8] reported a flammability test of coupons conducted using a Bunsen burner by the Federal Aviation Administration (FAA) in search of the best fire test gas to be used in a fire test. The test compared the burn time and flame length of two different gasses, methane and B-gas on different parts of the aircraft cabin. The flame length of the two gasses was almost similar with only small differences, in which methane gas shows the higher flame length and burn time of the materials considered in the test, and also showed no alteration in the flame characteristics on an average temperature of 1260ºC.

A fire-safe interior material on aircraft was developed by Lyon [9], who recognised that materials release heat differently when causing fire in the aircraft cabin. Different types of thermoset and thermoplastic polymers were used on the different materials, which reduces the rate of heat release by the materials. The insulating performance of the materials was assessed by Marker [10], who was among the first to conduct an experiment on a full-scale fuselage. The burn-through test analyses

the problem of fire burning through the materials which was caused by the increase of use of polymer materials on aircraft. The insulation experiment was conducted with different insulators in which oxidized polyacrylonitrile fibre (OPF) with polyimide showed an incremental burn-through time of six minutes over the previous fuselage insulator that only withstood 2 minutes. The data of past accidents were gathered and analysed statistically by Cherry and Warren [11]. The results showed an increase in loss of life by fire accident either by post-crash fire or by fire from other sources and their work has proved the advantages of fuselage fire hardening by using fireproof materials. Upon these findings, FAA proposed flame fire experimental methodologies for aircraft materials [12]. Dodds *et al*. [13] were the first to conduct the research of the response of composite structures under fire loading where laminate composite was developed to overcome the problem with fuselage fire.

This review work was based on considering different firewalls on aerospace application based on their structures (polymers, synthetic fibre, natural fibre and sandwich panel of different materials) and the burn-through time of these materials. The main issue associated with the composites materials used in aircraft structures is most of the composites used are flammable in nature and can easily ignite; this causes the loss of lives of passengers and crew and their valuables in the aircraft. Additionally, some of the materials used are heavier than others.

The main objective of this review is to identify the main materials to be used in constructing aircraft materials that are flame resistant and lightweight. The other properties of the materials are corrosion resistance as well as high thermal resistance, to reduce the tendencies of catching fire in aircraft. The firewalls in the aircraft are most needed at the fire-designated zones of the aircraft engine to prevent any leakage of fire from the engine. Therefore, there is a need for the next generation aircraft composites to be of lightweight materials in constructing aircraft structures such as the hybrid component of natural fibres and some other synthetic fibres. Likewise coating the existing aircraft materials with high-temperature coating agents like silica aerogel is also recommended[3, 4, 14].

II.AIRCRAFT ENGINE REQUIREMENTS

The FAA has established the Advanced Fire Safe Materials Research Program to meet the requirements of the Aviation Safety Research Act of 1988. The main aim of the program is to identify the main behaviour that exists between the composition and structure of materials in the event of fires in an aircraft fire designated zone. It aims to come up with a new material or a combination of materials that can withstand a high temperature within the stipulated time [15].

The following factors are some of the quality requirement for the aerospace industry:

1. Low friction and high wear resistance.
2. High temperature and thermal shock stability.
3. Dimensional stability across broad temperature range.
4. Low out-gassing under high vacuum conditions.
5. Thermal management and fire protection.
6. Electrical insulation across broad temperature range up through high voltage.
7. Broad chemical compatibility.

The materials used for aerospace firewalls include the following: metals and composites.

1. Metals

Lukkassen and Meidell [16] described metals as the main component of aircraft body design and construction. The following are the common characteristics of metals and their alloys: hardness, malleability, ductility, elasticity, toughness, density, brittleness, fusibility, conductivity, contraction and expansion. Among the metals used in aerospace industries are aluminium, steel and titanium.

Aluminium:

Aluminium is the main source of aircraft materials. It is lighter than steel and is resistant to corrosion and other environmental degradation. It is malleable and ductile, and when combined with different volumes of other metals forms alloys which are used in the aircraft construction. Aluminium needs little number of welds, and is less expensive than steel and other metals [16].

HPS-485W or HPS-70W:

HPS-485W or HPS-70Wis the latest type of steel used today. It has upgraded welding and toughness properties, is lighter and three times stronger than ordinary steel with a notable increase in strength and performance. This type of steel has applications in the aerospace industry and in steel bridge structures [16].

Titanium:

Titanium is one of the structural members used in constructing aerospace equipment and missiles. It is 45% lighter than steel, can withstand high temperatures with a melting point of 1500°C to 1735°C and is as strong as steel. A titanium-based alloy for the aerospace industry has the following properties: exceptional wear resistance, corrosion resistance, heat resistance, toughness, and strength, low coefficient of expansion and elastic in nature [16].

2. Composites

Two or more materials are combined together to form a composite to attain the desired property of the material needed that has higher ranking in terms of application than those of the main components of the materials. There are various classes of composite materials including glass coated metal, plastic or metal laminated corrugated paper, fibre-glass strengthened cement, stainless steel clad, carbon steel, fibre reinforced plastics, and steel or glass reinforced rubber [17, 18]. Currently, there are some composite materials that are used in aerospace industries by reinforcing the matrix composite with materials such as epoxy and aluminium, these composite are called advance composites. Examples of such composites are graphite/epoxy, Kevlar/epoxy, and boron/aluminium composites. Composite provides the modern outcome of aerospace materials with a remarkable strength, stiffness, and chemical and temperature resistance.

The followings are the classification of composite materials: Polymer Matrix Composites (PMCs), Metal Matrix Composites (MMCs), Ceramic Matrix Composites (CMCs) and Carbon Matrix Composites.

Polymer Matrix Composites (PMCs):

Polymer Matrix Composites (PMCs**)** are made up of different uninterrupted fibres bonded jointly by an organic polymer matrix. PMCs are sub-divided into two forms, reinforced plastics and advanced composites. An advanced composite has an application as aircraft materials due to its high stiffness and strength, but has a higher price than the reinforced plastic. PMCs have a lightweight property coupled with high stiffness and strength, are resistant to corrosion and fatigue compared to metals. This class cannot work for a temperature below about 316°C since the matrix decomposes at high temperatures; but it has some limitations that limit its application in some part of aerospace because its operating temperatures are low, the thermal and moisture expansion has high coefficient, and low elastic properties in certain directions [19-21]

Metal Matrix Composites (MMCs):

Metal Matrix Composites (MMCs**)** are composites with at least two constituent parts; it basically comprises of a low-density metal, such as aluminium or magnesium, reinforced with fibres of a ceramic material, such as silicon carbide or graphite. The main advantages that this class has are resistance to wear, operable at high temperature, low coefficient to thermal and moisture expansion, higher elasticity, high thermal conductivity and high specific strength and stiffness. Three methods were used in developing this composite material which are, high-pressure diffusion bonding, casting, and powder-metallurgy techniques. The diffusion bonding and casting methods have been used for continuous-fibre reinforced MMCs. Discontinuously reinforced MMCs have been produced by powder metallurgy and pressure-assist casting processes. Metal matrix composites such as B/Al, Gr/Al, Gr/Mg, and Gr/Cu have been manufactured by diffusion bonding for prototype spacecraft components such as tubes, plates, and panels. Among the limitations of this class are that high processing temperatures and high density are needed, it is expensive in terms of high-performance fabrication, and has lower ductility and toughness [22, 23]. MMCs are mostly found in loaded surfaces, which mostly are applied in turbine fan blades, floor supports and helicopter rotor blades [24].

Ceramic Matrix Composites (CMCs):

Ceramic Matrix Composites (CMCs) are divided into a sub-group of composite materials and a sub-group of technical ceramics. The ceramic fibres are placed in a ceramic matrix; therefore, forming a ceramic fibre reinforced ceramic material. The ceramic matrix composite is normally categorised into two groups, oxide-based and non-oxide-based. The oxide-based CMCs contain oxide fibres and an oxide matrix such as Al_2O_3/Al_2O_3, while non-oxides contain carbon fibres with a carbon matrix (C/C), carbon fibres with a silicon carbide matrix (C/SiC), and silicon carbide fibres with a silicon carbide matrix (SiC/SiC) [25]. CMC materials by comparison have high strength, high toughness and resistance to chemical reactions at high temperatures of at least 1500°C and relatively low density [26, 27]. The main problem with this class is the erosion of the environmental barrier coating layer and de-bonding of it with CMC in the gas engine, since the hot surfaces of CMC components are coated by an environmental barrier coating to protect them from oxidation damage [28,29,30]. CMCs are mostly used in the hot section of the aero-engine, which mostly are applied in turbine aerofoils, turbine disks and linear combustors [24].

Carbon Matrix Composites:

Carbon Matrix Composites use carbon fibres in a carbon matrix. It is the strongest class of all these composites and can withstand a very high temperature of 3315°C.It is quite lightweight at 30% lighter than graphite fibres and 20 times stronger [21]. The main advantages of this composite are resistance to high temperature, low creep, suitable tension and compression, low density, and high thermal conductivity. Among the limitations are it is very expensive, can be harmful at high temperature possibly causing cracks in the fibre matrix bond, has low shear strength and is also brittle. Carbon–carbon is well-suited to structural applications at high temperatures, or where thermal shock resistance and/or low coefficient of thermal expansion are needed [31]. Carbon matrix composites find application in aerospace as electromagnetic interference shielding, which can be used in aircraft wings [24].Different composites have different operating temperatures with different locations in their applications as indicated in Table1.

Table 1: Composites with their Operating Temperature

Composites	Operating Temperature (ºC)
Polymer matrix Composites	316
Metal Matrix Composites	>1000
Ceramic Matrix Composites	>1500
Carbon Matrix Composites	>3315

3.Sandwich Panel

Sandwich panel is the combination of layers that comprises a low-density core placed between two relatively thin skin layers, making it three layers in total. Additional layers may be added up to five layers in total to boost the fire performance of the sandwich panel [32, 33]. A sandwich can also be constructed by composite layered materials which contain external covers of hard material (usually sheet metal) and a sticky bonded lightweight core material(s) to yield protection/insulation and other mechanical properties. This empowers the panels to have large span/weight ratios with a high level of thermal insulation [34]. The sandwich panel gives an excellent mechanical performance at minimal weight. Sandwich panels achieved a very high rigidity and distributed within its parts any flexural load applied to the panel; the main core under the load has the shear loads and generates a space in between the skins which take the in-plane stresses that is making one skin to be in compression and the other skin to be on tension. Aluminium Composite Panel and Honeycomb Sandwich Panel are the most used sandwich panels.

Aluminium Composite Panel:
Aluminium Composite Panel is a sandwich panel that utilizes a core that is any material that is not aluminium bonded on two thin aluminium sheets of flat panel and is normally utilized as an exterior aspect of aerospace structures and insulation. The composite can be coated with poly-vinylidene fluoride (PVDF), fluoro polymer resins (FEVE), or polyester paint, or painted with any type of colours. The composite can be manufactured with any type of colours be it metallic or non-metallic and can be made in different patterns to copy the form of other materials. Its advantages make it a useful material in the aerospace industry. It has fire retardant properties, lightweight, flexible and durable [35].

Honeycomb Sandwich Panel:
Honeycomb Sandwich Panel is the most efficient sandwich panel that has high mechanical performance and low weight. Honeycomb sandwich panel finds applications in the aerospace industry due to its ability to meet the tough requirements, but has a high cost of production [36]. Wahl *et al.*[37] reported two types of honeycomb structures, natural and artificial. The natural type includes beehives, honeycomb weathering in rocks, tripe, and bones, while an artificial honeycomb structure is produced by the application of layering; this is done in between two thin layers that are in tension as shown in Figure 1. The main advantage of these panels is their high specific strength.

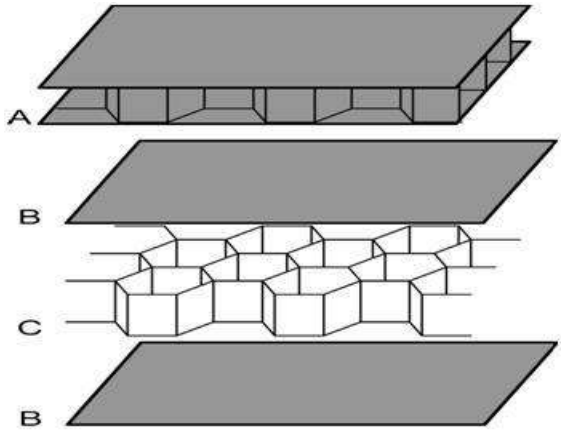

Figure 1: A composite Sandwich Panel (A) with a Honeycomb core (C) and Face sheet (B) [34]

III. FIRE RESISTANT AND FIREPROOF

A material can be fire retardant if the material can minimize the flammability of fuels or delay their combustion. These materials may be subjected to chemical agents, coatings such as fire-fighting forms or other physical action that made the materials fire retardants [38]. The fire retardant materials refer to the type of materials that can withstand a flame fire for 5 minutes at a standard temperature of 1100±80ºC[39].
Materials can be fireproofed according to the ISO 2685 standard so that it can withstand a fire up to 15 minutes [39]. Therefore, fireproofed materials are positioned in fire-designated zones of the aero-engine to prevent fires from leaking out of the zones. Federal safety guidelines stated that for the fire designated zone components, equipment and structures, seals in engine nacelles must be able to withstand a flame for 15 minutes. During this time, temperatures can rise as high as 1100°C. Modern engines now conserve fuel by employing increasingly high combustion chamber temperatures which expose seals to higher thermal stresses. The interior part of the engine casing is exposed to temperatures of up to nearly 315.5°C while the air flowing on the outside can be as low as -65°C.

Polymer-based materials include oxidized polyacrylonitrile-based (PAN) felt, aramid-based felt, melamine-based fabric, or hybrid aramid/inorganic fibre/felt. The aramid fibre is an artificially made organic polymer, made by turning a solid fibre from a liquid chemical mixture. This mixture has a very high strength and low density with a high specific strength. The advantages of this material are it does not ignite, melt, or drip; but decompose at about 425°C in air. The material is unchanged by a little amount of water vapour, it increases the performance of fire blocking materials, and this made the material flame resistant with a high tensile strength. It exhibits exceptional heat insulation properties with low thermal conductivity [40].

Hybrid aramid/inorganic fibre is the combination of aramid material and ceramic oxide. The main factors that made this fibre viable in the aerospace industry are its exceptional fire-resistant properties, high strength, and low thermal conductivity [41].

A ceramic-based material is made of Al_2O_3, SiO_2, and/or B_2O_3. The material has a steady temperature between -250°C to a temperature greater than 1100°C, with a thickness of 0.15 to 15mm, the area density of this material ranges from 50g/m^2 to 150g/m^2.The melting point of this ceramic-based material depends on the composition of the material considered. Silica-based ceramics has a melting point in a range of 1050°C to 2200°C depending on the composition. The ceramic compound is resistant to fuel flame and also to most of the organic and mineral acids [25].

IV. FIRE TEST RESULTS

According to the Advisory Circular AC20-135 [42], for the acceptable test criteria and philosophy for "fireproof" and "fire resistant" materials, components, and fittings, the specimen must be exposed to the required flame temperature and heat flux density for 15 minutes and 5minutes respectively. The material to be tested is expected to withstand a fire penetration through it within the expected time for the fireproof and fire-resistant classification. The sample to be tested should be exposed to a flame from any acceptable burner at the test working settings. The flame size and temperature shall be sufficient to sustain the demanded test temperature and heat flux density over an area of approximately 5"x5" for sheet materials and panels. All installations that are used in firewalls and in fire zones shall be fully engulfed in the flame.

Bartlett and Stratford [43] investigated the fire resistance certification of aircraft composites using an oxygen-acetylene heating tip. The experiment had compared the aluminium 2024-T3 Clad and the composite materials on the engine cowling, and the test conducted was based on AC20-107A [44]. The rated power of the oxygen-acetylene flame used was 11.76 kW and the required flame temperature was 1093± 67°C as measured by a K-type thermocouple placed ¼ inch from the face of the calibration plate. Six aluminium specimens were used, three for practice test and three for certification. The results obtained are shown in Figure 2.

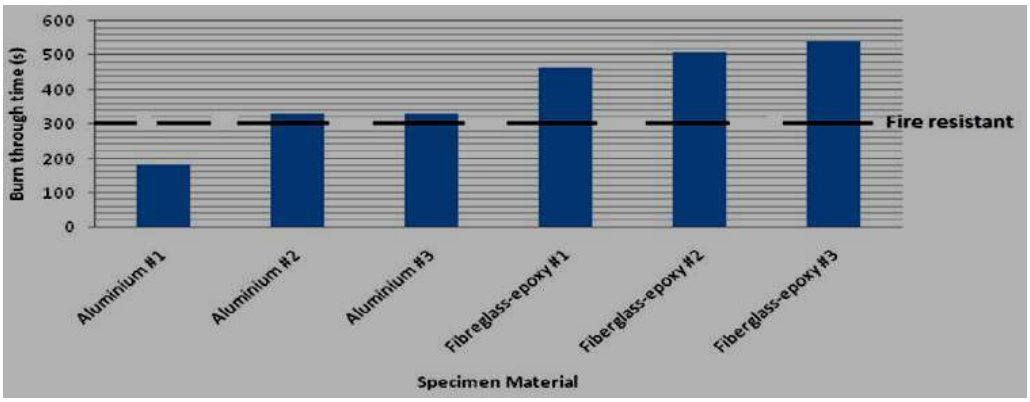

Figure 2: A graph of Fire resistance Test Result for Aluminium and Fibreglass-Epoxy Specimens [40]

The difference of burn-through time of aluminium #1, #2 and #3 and also fibre-glass-epoxy #1, #2 and #3 was due to the adjustment of standard torch handle knob, by using a precise flow meter known as Smith H1230. It is observed that the fibre-glass-epoxy specimens exceeded the burn-through time of aluminium, and therefore best to be used for the fire certification. Also clearly seen is that all the materials considered except aluminium #1 has the fire resistant characteristic, and none of them can be considered as fireproof.

Sikoutris [45] investigated the temperature at pre-test and post-test (°C), heat flux (kW/m^2) and burn-through time(s) of aluminium alloy (400x400x2.03mm), epoxy carbon fibre (400x400x3mm) and 5-ply GLARE (370x400x3mm). The GLARE material is a combination of aluminium 2024-T3 layer and glass prepregs. In the fire test, a correction for emissivity was made to some temperature as implied by their images. The correction was facilitated by the use of standard emissivity paint, having a value of 0.92. A band of the paint is applied to the rear of the sample and the emissivity is set to the

value in the imaging software. The experiment was based on the ISO 2685 Standard. From the findings, it was clear that aluminium alloy burns before the 5 minutes mark of fire resistant which indicates that aluminium alloy used does not have the required properties of resisting fire in aircraft cowlings. However, epoxy carbon fibre and 5-ply GLARE did not burn even after 15 minutes, which shows that they are fireproof material, showing a good characteristic of materials for use in aircraft cowlings. The data for the first test shows highly varying values but the second test gave a steady value of around 0.80 for most of the test when the temperature had reached a high steady value.

Tran [41] investigated the burn-through time of lightweight ceramic/polymeric fire barrier materials and studied the aircraft thermal/acoustical insulation blanket applications. The materials examined include SiO_2-based ceramics and some fire-resistant polymers where the samples were inserted into a fibre-glass blanket and burned using a medium-scale burn-through 11 apparatus. The burner calibration shows an average temperature of 1058°C for all seven thermocouples and 172 kW/m^2 averaged heat flux. The results obtained were almost similar to the results in a large-scale fuel fire test on a real aircraft fuselage [28]. The heat flux result was recorded from two calorimeters placed at the rear side of the sample and shown in Figure 3.

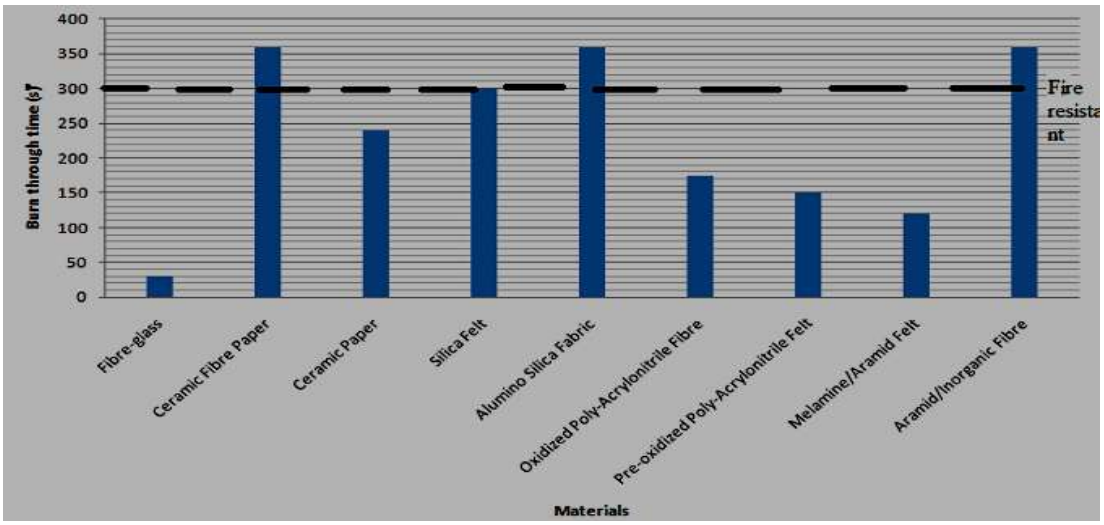

Figure 3: A graph of Burn-through Result of the different Samples [38]

The above result shows that ceramic fibre paper, silica felt, alumina silica fabric and aramid/inorganic fibre are the only fire resistant materials among the samples considered. These are indeed the samples that are considered to be fire resistant. Samir *et al.*[46] conducted an experiment on two sample sizes of aluminium alloy of ¼ inch thickness (4"x4" and 12"x12") using a NexGen Burner and found out that the smaller sample can survive longer under the same burner operating conditions. When the fuel flow rate was varied, as the fuel flow rate increased, the damages produced by the flame were more severe. But as mixing/secondary air was varied, no appreciable change was observed in the flame calibration. As Jet A fuel flow rate increases (by varying the flow rate), the heat flux and the temperature increase rapidly. On the contrary, when the air flow rate was increased, the heat flux was not in a stable state, it decreases and increases, and likewise the temperature. Therefore it is clearly understood that varying the fuel flow rate increases the heat capacity of the flame while increasing the flow rate of air does not have any significant effect on the flame. Hooijmeijer and Vlot [47] reported that GLARE material is a type of material that has two different burn-through characteristics, the aluminium layer which is thin burn-through very fast when exposed to fire, then the glass-fibre prepreg layer which is in an epoxy matrix will be directly be exposed to a fire flame of around 1100±25 °C as it is in Abu Talib & Mohammed [48]. The glass–fibre will not allow the flame to penetrate the layer, therefore generating a fire blockade. Since the epoxy matrix cannot withstand the heat, the fibre layer then carbonised on its thickness, which causes the delamination of the laminate which separated the layers and allows air to pass between the layers and act as a protector (insulator). The unburnt aluminium layers in the laminate are protected by the insulating air barriers and by the carbonised epoxy. The non-exposed side of the aluminium will remain intact with a lower temperature. The experiment was conducted based on AC 20-135 methods, which showed that aluminium (1.5 to 2.0mm thickness) burns in 90 seconds. However, while in the GLARE material no burn-through was seen for the period of time considered. The results of the test shown in Figure 4 indicate the percentage different layers of GLARE that meet the burn-through requirements,

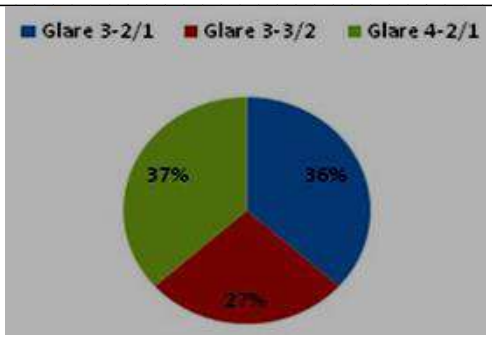

Figure 4: A Pie chart of Glare [44]

When the fibre laminate Glare is exposed to high temperature, only the outer layer will be affected, the non-exposed side will be insulated from the fire by the air barrier making this side stays relatively cool.

Abu Talib *et al.* [3] uses ISO 2685 burner to test different types of polymer-aerogel fibre metal composites.The experiment was based on fire certification where the burner calibrated according to ISO2685 standard using three K-type thermocouples. Three composites of 250 mm x 300 mm x 2.5±0.2 mm aluminium alloy sheets and a mixture of different silica aerogel with epoxy resin/hardener was made by dissolving one percent of silica aerogel in an epoxy resin. The average result of the three composites considered (Hamzel®, Enova® IC3100, and GEA™ 0.125), shows that Enova® IC3100, and GEA™ 0.125 were fireproof composites (withstand flame fire for 15 minutes), while Hamzel® was fire resistant composite (withstand a flame fire of more than 5 minutes but less than 15 minutes). Figure 5 shows the result obtained.

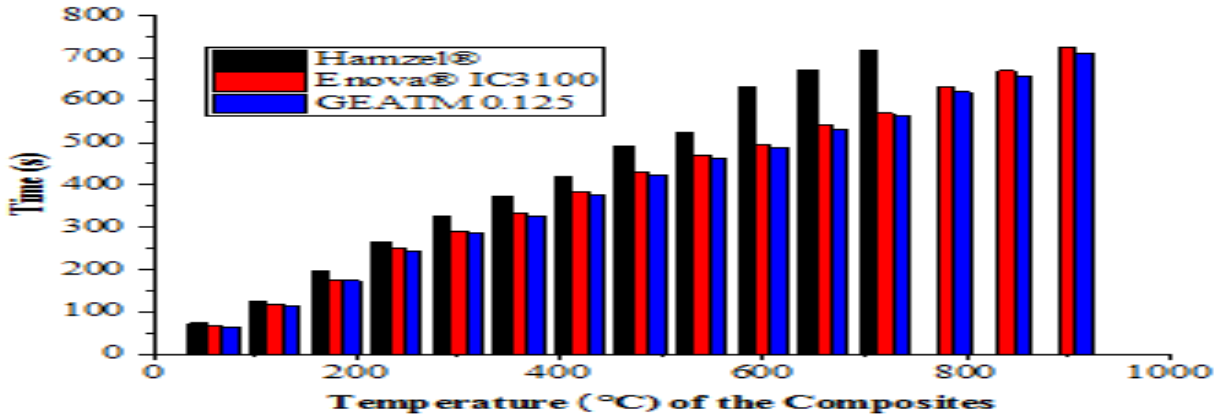

Figure 5: Rear Face Temperature of the Composites [3]

The GEA™ 0.125 composite has the highest flame resistance as compared with Enova® IC3100 composite. Likewise, Abu Talib*et al*. [14] conducted an experiment based on the effect of different Weight-age of Enova® IC3100 silica aerogel on aluminium alloy composites using ISO2685 aviation standard Fire-test; in which 300 mm x 300 mm x 0.4 mm aluminium alloy 2024-T3, 300 mm x 300 x 0.6 mm flax, Enova® IC3100,and HL002-TA/B epoxy resin/hardener were used in fabricating the composites. The first test was conducted on three samples of 1.0%, 1.1%, 1.2% and 1.3 of Enova® IC3100 silica aerogel to the epoxy polymer. The test shows that 1.0 and 1.1% were fire resistance composites, while 1.2 and 1.3% were fireproof composites. While on the second test, the three samples considered were 0.8%, 0.9%, 1.0% and 1.1% of Enova® IC3100 silica aerogel to the epoxy polymer with flax. The test shows that 0.8 and 0.9% were fire resistance composites, while 1.0 and 1.1% were fireproof composites. Figure 6a and b shows the rear face temperature of the composites. It shows that addition of flax fibre (natural fibre) increases the thermal conductivity of the composites.

Also, an experiment was conducted on a fire test by ISO 2685 burner on fibre metal laminate composites by Mohammed *et al.*[4], whereby aluminium alloy 2024-T3, carbon fibre (synthetic fibre), kenaf and flax (natural fibres) with an epoxy resin/hardener were used to form the composites. The four composites were fabricated were carbon fibre reinforced aluminium alloy with alternating aluminium alloy (CFRAA1), carbon fibre reinforced aluminium alloy with aluminium alloy at front and rear face (CFRAA2), carbon fibre flax reinforced aluminium alloy with aluminium alloy in front and rear face (CFFRAA), and carbon fibre kenaf reinforced aluminium alloy with aluminium alloy at front and rear face (CFKRAA). Three of the composite shows fireproof properties, while carbon fibre kenaf reinforced aluminium alloy shows fire resistant properties. Figure 7 shows the thermal conductivity result of the four composites.

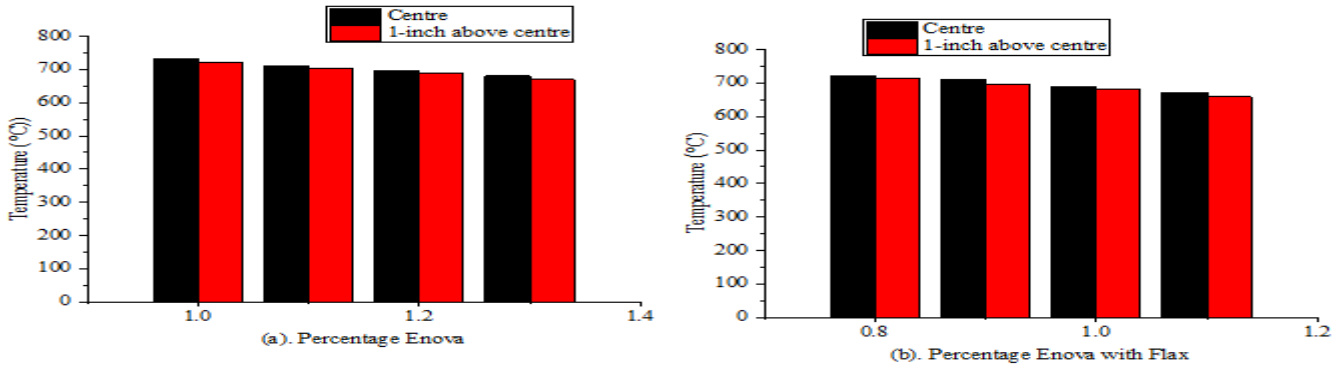

Figure 6: Rear Face Temperature of the composites [14]

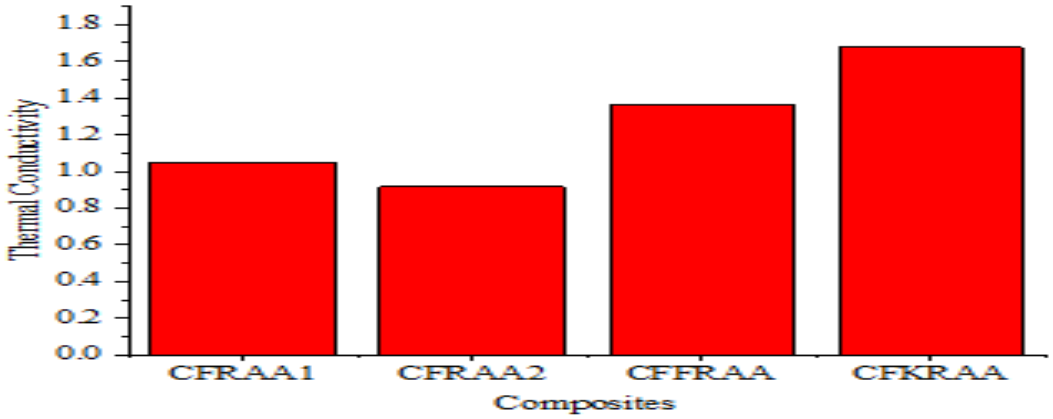

Figure 7: Thermal Conductivity of the Composites[4]

IV.DISCUSSION

Different types of materials were considered as the combination of the materials to be used as fire retardants in various sections of the aircraft. For the aero-engine application, fireproof materials were used to act as flame retardants. Some of the materials used are carbon fibre and phenolic/epoxy resin, honeycomb structure of glass fibre mat impregnated with polyimide resin, silica aerogel with epoxy resin/hardener, flax and kenaf (natural fibre), graphite yarn with epoxy matrix, aluminium alloy with silicone rubber sealant and also graphite fibre embedded with silica.

Silica gives polyimide resin and firewall the required low thermal conductivity and stability in flame fire. Most of the composites considered in the review are used in aircraft cabins, some as decoration and some as fire resistant in the cabin.

Other composite materials which are used on the aircraft fuselage and engine nacelle, cause some drawback due to the addition of weight to the aircraft besides being relatively difficult and expensive to maintain. Natural fibres and aerogel despite being lightweight are also, environmentally friendly, but should be sandwiched with highly reinforced fibres to reduce the weight of the materials used in that section, but they are used in other parts of the aircraft that do not require high-temperature imperviousness.

Some of the composites that were made from spray coating, has the drawback of cracking, peeling and time-consuming to inspect. The blanket composite insulation system to the engine nacelle adds more weight and also consumes more space in the structure. Additionally, materials like stainless steel and quartz that are used as fire protection materials in the engine nacelle add yet more weight to the structure. These problems can be overcome by using lightweight composites, which can double as fireproof materials in the aero-engine.

V. CONCLUSION

A number of composite polymers were studied, which indicated that aluminium composite is becoming worldwide applicable materials for the aerospace industry because of its high wear resistance, strength to weight ratio and thermal resistance, but has a limitation of burning before it reaches the required fire resistant time. Aluminium alloy alone cannot be used as a fire resistant material for the aircraft engine nacelle, whereby three methods were tested in this review and the entire

test failed. By using an oxygen-acetylene heating tip, the alloy burned averagely for 280 seconds at an average distance of 15 inches from the heating tip. Likewise using an ISO 2685 standard burner, the aluminium alloy burns at an average of 180 seconds with a standard distance between the burner face and the specimen of 3 inches. The aluminium alloy using AC 20-135 burns at an average of 90 seconds. This shows that AC 20-135 did more damages to the specimen than ISO 2685. Most of the composite materials can be used as fire resistant and fireproof materials to increase the fire safety of the parts of the aircraft which are made up of glass/phenolic, which performed fairly well in a fire scenario. Carbon fibre reinforced aluminium laminate composites for synthetic fibre alone and hybrid with natural fibre shows a fireproof characteristic, likewise silica aerogel composites. There is a need to explore more composites that can be used in aircraft engine nacelles to overcome the problems of the existing composites materials, as well as other materials used. Therefore, it is recommended that the materials and composites be used in an aircraft structure to be coated with fire-resistant substances like silica aerogel.

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